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# PROCEEDINGS

## AMERICAN SOCIETY OF CIVIL ENGINEERS

FEBRUARY, 1952

# LAKE MICHIGAN EROSION STUDIES

By Colonel John R. Hardin, M. ASCE, and
William H. Booth, Jr., Assoc. M. ASCE

WATERWAYS DIVISION



**Headquarters of the Society**
**33 W. 39th St.**
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AMERICAN SOCIETY OF CIVIL ENGINEERS
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## PAPERS

# LAKE MICHIGAN EROSION STUDIES

By Colonel John R. Hardin,[1] M. ASCE, and
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### Synopsis

The state of Illinois, acting through the Division of Waterways, has become increasingly concerned with the erosion problem of Lake Michigan within the state limits. As a result, the state requested a cooperative beach erosion control study to determine the best plan of improvement for stabilizing the shore line. This paper deals with the erosion conditions, prior corrective actions, structures, and describes the protective measures that have been recommended.


### Introduction

A cooperative study of the erosion of the shores of Lake Michigan in the Chicago area was completed by the Corps of Engineers (United States Army) and the State of Illinois in 1950. The problem encountered and the considered judgments of the cooperating agencies as to corrective measures required are believed to be of interest to other engineers facing similar problems. The problem involved not only the protection of existing property, but also the solution of a pressing social need for more recreation facilities for the people of Chicago. Although the economics of the improvements and the sharing of cost are important features of the study, this paper is devoted only to the general problem of shore erosion and protection.

The shore lines of the Great Lakes have changed continually for thousands of years. Before the time of written history, these changes were primarily of glacial nature. Within historic times, Lake Michigan has been eroding its western shore from the vicinity of Green Bay, Wis., southward to the vicinity of 55th Street in Chicago. The main physical forces that are responsible for this erosion are wind, wave, and current action. The principal direct agent in producing the erosion is wave action that breaks down and stirs up the material.

Note.—Written comments are invited for publication; the last discussion should be submitted by **August 1, 1952.**

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The eroded material moves generally southward, until it reaches the vicinity of 55th Street, where accretion begins to balance erosion. At the south end of the lake, the eroded material enters a natural collecting ground, forming beaches and the famous sand dunes of Indiana.

These changes in the shore line and beaches did not disturb, to any great extent, the forefathers who settled along the lake shores. If the beach was washed away by storm waves or by currents, the early settler merely built another cabin, of easily obtained native materials, a few hundred feet further inland and went about his business.

However, the solution of the problem resulting from beach erosion and changes in shore line is not that simple in the twentieth century. Quite literally, billions of dollars' worth of property fronts on the lake along the Illinois shore line. There are thirteen cities and villages, two military reservations, and thousands of commercial, industrial, residential, and recreational properties along the 58 miles of shore line within the state of Illinois.

Since man began to build structures and modify the shore line, the natural processes have been disturbed at various points so that numerous local exceptions may be made to the foregoing erosional and depositional trends. Outstanding examples of these exceptions are the areas of accretion found north of artificial structures, such as the harbor structures at Waukegan and Wilmette, and the bulkhead projection north of Foster Avenue in Chicago. Another example is the general absence of the appreciable littoral drift south of Foster Avenue. Thus it may be said that the problem of shore line protection against erosion is a problem created or aggravated by civilization.

## Physiographic Sections

A detailed examination of the Illinois shore line of Lake Michigan indicates that, for purposes of erosion control, this shore line may be logically divided into sections based upon both the natural and artificial features. The four divisions adopted for the purposes of this study are as indicated in Fig. 1. These divisions are: (1) Northern lake plain section; (2) lake border moraine section; (3) southern lake plain section; and (4) the artificial fill section.

(1) *Northern Lake Plain Section.*—This section of the shore extends from the Wisconsin-Illinois state line (actually from Kenosha, Wis.) to Waukegan Harbor. It is an eroding section of the shore, except north of the Waukegan Harbor structures that form an inpounding area for the natural shore drift moving southward. This general section of the shore is little developed, except at Winthrop Harbor, Zion, and Waukegan. The Lake is fronted by a relatively low plain with old beach ridges and dunes, and the erosion taking place represents essentially a recapture of the ancient glacial lake deposits by the present lake.

(2) *Lake Border Moraine Section.*—This section of the shore extends from the south side of Waukegan Harbor to the jetty at Wilmette Harbor. Here the shore consists of bluffs having heights as much as 90 ft above lake levels. A beach, with a maximum width of 200 ft and an average width of 75 ft land-

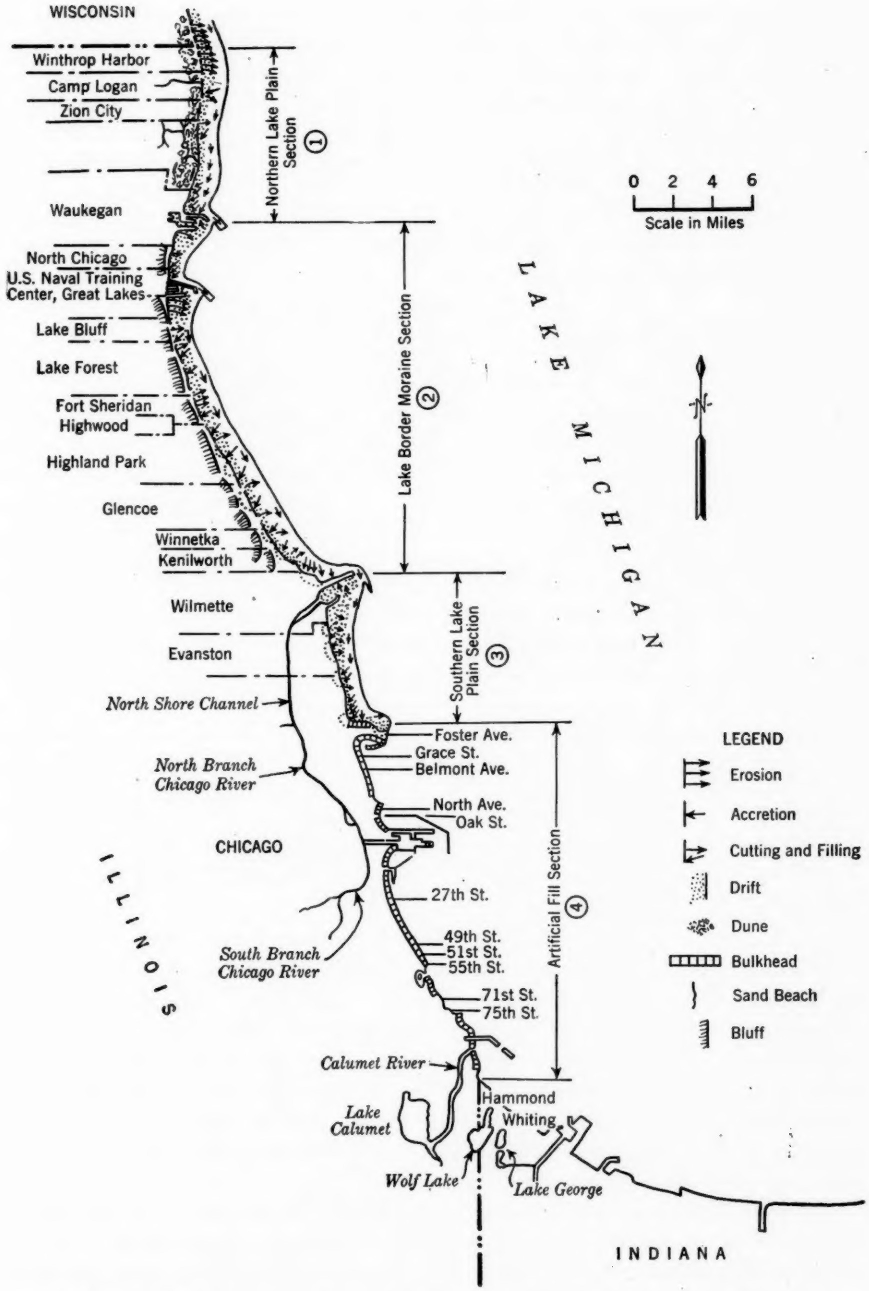


Fig. 1.—Beach Processes and Littoral Drift on the Illinois Shore of Lake Michigan

ward of the low water datum (El. 578.5 ft above mean tide, New York datum), lies along the base of the bluff. The shore along this section is subject principally to erosion as far south as Winnetka; from that point to Wilmette Harbor there is an impounding area largely created by the jetty at the harbor. Although this shore has a natural beach along most of its extent, high lake levels combined with severe storms cause damage in some sections to the high steep bank immediately behind the beach line.

(3) *Southern Lake Plain Section.*—This section of the shore extends from Wilmette Harbor to Foster Avenue in Chicago. It includes that portion of the shore fronting the city of Chicago that has not been significantly modified by artificial fill. The shore is highly developed along its entire extent, and groins or short bulkheads and sea walls are common. Under natural conditions the northern part of this section was subject to marked erosion and now to a large measure has been controlled by structures. The large artificial fill that extends into the lake at Foster Avenue has created an impounding area, and at that point the drift from the north accumulates to form a wide beach area.

(4) *Artificial Fill Section.*—This section of shore extends from Foster Avenue south to the Illinois-Indiana state line and is predominantly one of artificial fill. In this section the shore, with the exception of beaches, is mainly protected by bulkheads or sea walls. Relatively short reaches of the shore, from 67th Street to 75th Street in Chicago, and from the south end of Calumet Part to the Illinois-Indiana state line, represent the natural shore line, but even these will probably be altered eventually by filling operations. It is believed that the bulk of the present natural drift from the north comes to rest at Foster Avenue. When this structure has impounded material to its capacity, then some natural drift will be available for the shore to the south. The improverishment of the drift by the Foster Avenue impounding area, combined with the great depth of water in front of the filled land to the south, has resulted in marked changes in the natural shore line trends and in the conditions of shore drift. As a consequence, reliance for bathing beaches has been largely shifted to the creation of artificially nourished beach areas along this section of shore line.

## Shore Line Changes

The data on shore line changes are available for four periods: 1872–1873, 1909–1911, 1937–1938, and 1946–1947. It was difficult to make a definite comparison of this data since the first two periods were taken from old surveys. The data for the third period were obtained from aerial photographs and a field survey made by the State of Illinois, and the data for the fourth period were obtained from a survey made specifically for the erosion study. The changes in the shore line were analyzed within the framework of the four sections of the shore line previously described.

The northern lake plain section is generally characterized by erosion of the shore line during the entire period, except that portion immediately above the Waukegan Harbor breakwater. The data indicate that the average annual rate of recession of the shore line ranges from about 10 ft at the Wisconsin-Illinois state line to about 1 ft at the Illinois Beach State Park, with accretion

of about 28 ft at Waukegan Harbor breakwater. The offshore depth change has followed the general trend of the changes in the shore line.

The lake border moraine section contains considerable variation in local conditions of shore line and offshore depth changes. The condition of the shore line is chiefly dependent on the influence of the breakwaters at Waukegan, Great Lakes, and Wilmette Harbors. Immediately below Waukegan Harbor only small changes have occurred, as a result of riprap protection of the shore. South of the Great Lakes Harbor and extending into Lake Bluff, erosion amounting to about 4 ft annually has occurred. In general, the shore line from Lake Forest to Kenilworth has been stable during recent years, with accretion occuring at Wilmette Harbor.

The southern lake plain section has been subject to both erosion and accretion during the period from 1872 to 1946. The shore line has varied only 1 or 2 ft annually. The offshore depth contours in this section have, in general, moved lakeward and considerable amounts of material have been deposited in the areas south of Wilmette Harbor and north of Foster Avenue. The heavy offshore deposit south of Wilmette Harbor is believed to be the result of the lakeward diversion of the shore drift, caused by the projecting shore conformation and jetty at the harbor.

The artificial fill section has a shore line that has been extended lakeward with artificial fill for almost the entire length. The fill has been stabilized in a large measure by placing of riprap and the construction of bulkheads, groins, and similar structures. This alteration of the natural conditions has made it difficult to determine whether natural erosion or accretion has occurred.

## Factors Affecting Erosion

*Waves and Currents.*—Of all the movements of the lake water, waves are the most significant in considering shore protection. Most waves are generated by the action of wind upon the water surface, and their direction and magnitude generally depend upon the direction and intensity of the wind. The action of the wave against the shore induces an alongshore current that moves material. High lake levels allow the waves to reach farther inland for this erosive action while low lake levels may reduce depths of water over offshore bars so that favorable wave action may carry material from the bars to the beaches.

No special observations were made to determine the strength of the shore currents along the Illinois shore, but some data were obtained from the Department of Geology, Northwestern University, on current observations at Evanston, Ill. These observations covered a period of 18 months and indicated that when currents were present, the prevailing movement is southward about 65% of the time, and northward about 35% of the time. The southward moving currents generally had higher velocities than those moving north, with maximum observed values near shore of about 3.5 ft per sec southward. The velocity of the currents was determined by observing floats in the zone just outside the breaking waves. The stronger southward moving currents develop a greater drift of sand in that direction, which is in conformity with observed accumulation of sand on the north side of existing structures.

*Littoral Drift.*—The estimated annual rates of shore drift along the Illiinois shore are as follows:

| Section | Drift, in cubic yards |
|---|---|
| Northern lake plain | 90,000 |
| Lake border moraine | 57,000 |
| Southern lake plain | 40,000 |
| Artificial fill | Negligible |

*Protective Structures.*—It appears that, in the past, local judgment has generally determined the method or methods to be used in improving and stabilizing the shore line. As a result wide differences in the character, planning, and design of structures are evident. Some have been effective, and others have been useless. A large number and variety of structures, many dating prior to 1900, have been constructed in an effort to retard erosion and to maintain a beach. Most of those constructed of wood as a basic material are now completely disintegrated, or so badly in need of repair as to make them ineffective. Other old types, especially concrete or steel bulkheads, have held up very well and continue to provide effective protection. High lake stages have again put emphasis on shore protection and, as a consequence, a number of new structures, groins in particular, have been constructed.

There are many types of protective structures in use along the Illinois shore line. The predominant types are: (*a*) Solid groins; (*b*) permeable groins; (*c*) breakwaters or jetties; (*d*) hooked piers; (*e*) submerged breakwaters; (*f*) bulkheads and sea walls; and (*g*) riprap revetment.

(*a*) Solid Groins.—Solid groins have been the most widely used for stabilizing the shore line and creating beaches. They are as numerous as all other protective structures combined, and comprise more than three-fourths of all beach building types. They have been build most extensively in the lake border moraine section wherein the littoral drift is generally adequate to build and maintain a beach.

The height of the groins has been observed to have considerable effect on their functioning. Those that have heights not exceeding 3 or 4 ft above low water datum have retained material on their north side and yet have permitted some material to be carried over the top so that beaches are found on both sides. The higher groins, that have prevented the flow of drift over them, have starved the beach "downdrift," resulting in a saw-tooth configuration in the shore line. Long groins (exceeding 250 ft in length) interrupt the drift and also produce the saw-tooth effect especially if the groins are comparatively high. It has been noted that short groins (less than 100 ft in length) have been outflanked unless the landward end has been protected by a bulkhead or riprap to prevent erosion. Solid groins of any type can function successfully only insofar as the supply of material is adequate for maintenance of the beach.

(*b*) Permeable Groins.—Permeable groins of a patented type are comparatively new to the Chicago area, and almost all of this type have been built since 1938. They were developed on the theory that structures with increasing permeability from the bottom to the top and from the shore end lakeward would impound sufficient material to stabilize the shore line, create a beach of

equal width on both sides of the structure, and pass enough drift to avoid starving the beach "downdrift." Generally the groins have been constructed of precast concrete members, built in crib fashion to the desired height and length, and usually topped with a concrete deck slab. The high costs of these reinforced concrete structures, however, has led to the use of permeable steel groins. These latter groins are constructed of solid steel sheets piling with an extensive series of holes or slots cut in the web.

Examination of the beaches in the Chicago area indicates that the permeable type of groins do pass enough material to avoid starving the shore "downdrift." However, there is evidence to indicate that in many cases they do not retain sufficient material to hold a protective beach, especially where there is a small amount of littoral drift.

The effectiveness of the groin in retaining material is increased by a reduction in permeability. This has been accomplished by the use of the steel sheet pile permeable groins, in which the permeable area has been greatly reduced and is limited to the upper portions of the offshore end of the groins. The tops of these groins are stepped down toward the lakeward end. This type of permeable groin approaches the concept of the low sloping impermeable groin.

(*c*) Breakwaters or Jetties.—Breakwaters are similar in construction to the solid groins, but are larger in cross section, heavier in construction, and greater in length. They are intended primarily as navigation improvements, and, as such, are located chiefly at the harbor entrances. Because of their length, they affect the movement of material along the shore to the extent that all, or a major portion, of the littoral drift is impounded. A large fill is thus accreted on the north side of the breakwater, as has previously been mentioned for the harbors at Waukegan and Wilmette, although the beaches to the south are starved. Studies of some of the harbors indicate progressive shoaling in the offshore zone on the south side, probably caused by the trailing bars near the outer end of the breakwater, or possibly by temporary reversal of littoral drift.

(*d*) Hooked Piers.—These structures are designed to retain material and prevent its further movement from the area of entrapment or placement. The hook feature gives a pleasing appearance, and was designed to provide additional impounding capacity without constructing the outer end of the pier in deep water. The structure at Loyola Park (Chicago, Ill.) is 800 ft long with the outer end built at an angle of 45° toward the north, and the pier at Montrose Avenue is 2,420 ft long with its outer end curved in the shape of a question mark. The pier at North Avenue is similar to that at Montrose Avenue. These piers, about 7 to 8 ft above low water datum, have been very effective in intercepting drift or retaining artificial fill. Other structures have been used in conjunction with piers to assist in retaining the material in place. Groins have been constructed north of the pier at Loyola Park, and groins and a submerged breakwater are part of the system assisting the pier at North Avenue. No other structures have been erected to assist the pier at Montrose Avenue. The structure at Loyola Park has intercepted the shore drift and

created beach to a line predicted at the time of construction, and the groins have effectively slowed down the transport of the impounded material. The structures at North Avenue have retained 75% of the placed material over a period of 5 years; the lost material probably escaping around the end of the pier.

(*e*) Submerged Breakwaters.—There are four submerged breakwaters in the study area, all within the city limits of Chicago. They are located offshore, across concave sections of the shore line, and are constructed either of steel piling or of rubble mound. They are constructed parallel to the shore line in water depths of 13 to 20 ft and located approximately 500 ft offshore. The top elevations of the breakwaters vary from 2 to 6 ft below low water datum. The primary function of submerged breakwaters is the retention of filled material landward, without creating a landlocked pond. The tops of fills placed at the submerged breakwaters were generally from 3 to 5 ft below the tops of the submerged structures. Insofar as can be determined, the breakwaters have retarded direct offshore movement of the filled material, although some scouring along the landward and lakeward sides of the vertical steel piling breakwaters has been noted. In addition to their function of retaining the sand fill, they were designed to act as a baffle in breaking up the waves crossing the structure. Obviously, the reduction in wave energy shoreward of the submerged breakwater reduces the movement of fill material on the beach.

(*f*) Bulkheads and Sea Walls.—These structures are essentially walls built parallel to the shore line to limit the shoreward movement of the waterline, to protect the shore from wave action, and to retain backfill in place along the shore. They do not protect the beach but under severe storm conditions may promote erosion of the beach fronting them as a result of scour from wave action. Sea walls differ from bulkheads primarily in size and in type of material used for construction. The sea walls in the study area are massive structures built of square-cut limestone blocks each weighing 5 to 15 tons. Bulkheads, used as protection along this section of shore, are constructed of steel sheet piling, concrete, timber piling, or of timber piling cribs filled with stone. Sea walls have been built most extensively within the city limits of Chicago, where considerable Park District property has been protected by that method. Well-constructed bulkheads have proved effective in protecting the shore from erosion, except during unusual storms. The sea walls in Chicago have prevented erosion practically at all times, although water from breaking waves has caused some delay to traffic on adjacent highways where walls are not of sufficient height.

(*g*) Riprap Revetment.—Two types of stone riprap shore protection have been used, differing primarily in the way the material is placed, and the foundation upon which it rests. Dumped riprap, ranging from construction material debris to 20-ton capstones, has been used as a protective measure in almost every community along the lake. Industries, in particular, utilize that method extensively. Objection to dumped riprap is that it is not as pleasing in appearance as placed riprap. Placed riprap is much less common than dumped riprap, but where it has been used, principally by the Chicago Park District, it is found to be quite effective and very serviceable.

*Ice Conditions.*—The ice conditions along the shore line of Lake Michigan are to be considered in studying the erosion problem. During average years, ice usually starts to form along the Illinois shore of Lake Michigan about the middle of December. Generally, the initial ice sheet attains a thickness of 6 to 8 in. and extends for some distance lakeward. This initial condition does not remain unchanged, but is usually followed by upheavals as a result of storms and wave action, with the consequent formation of ice hummocks and windrows along the shore. The ice becomes honeycombed and weakened about the middle of March, forming into moving fields and windrows. The ice field drifts in all directions, depending upon the direction of the wind. During severe winters shifting ice fields, forced ashore by strong winds, often are piled to heights up to 20 ft, and offshore windrows form to the same heights or even higher. During January, 1948, ice was piled as much as 15 ft above the water surface and extended 50 to 100 ft behind the sea walls and bulkheads in Chicago. These huge ice masses, piled on the shore, do not, in general, cause damage to beaches or riprap and may provide additional protection against damage from storm waves. These masses, however, may cause damage to other protective structures, because of the tremendous load superimposed thereby, and, in some cases, individual members of structures may be bent or broken when the waves undercut the base of the ice. Floating ice has damaged many timber structures by abrasive action.

## Recommended Improvements

The State of Illinois, acting through the Division of Waterways, held three public hearings in 1947 to ascertain the views of local officials, property owners, and interested persons with reference to the problems in their areas and the plan of improvement desired. The public hearings were limited to discussion of the improvement to public property, and no views were obtained from private property owners other than in a general way. The views obtained were given careful consideration in developing the plan of improvement.

As previously mentioned the shore line has been divided into four sections:

1. The northern plain; 2. the lake moraine; 3. the southern plain; and 4. the artificial fill.

1. *Northern Plain Section.*—As stated previously, this section of shore line is eroding in the northern part of the area. In general, erosion caused by wave attack of the unprotected shore may be reduced by building a beach of suitable profile to dissipate the wave energy. This is considered one of the best methods of protection, especially if the supply of sand transported by littoral currents is sufficient to maintain the beach. The rate of drift in this section is moderately heavy when compared with the sections south of Waukegan. The construction of impermeable groins in this area would impound material for the desired protection, and provide a beach for recreational use. The width of the beach desired would control the length of the groins to be constructed. A typical section of the proposed shore improvements is indicated in Fig. 2. This design is based upon retaining sufficient drift to achieve the desired results, yet allowing a portion of the sand to move downdrift to nourish other areas.

If groins were constructed along the entire reach, the littoral drift would be absorbed or discontinued and might result in erosion to the south. The number of groins constructed per year should be governed by the amount of littoral drift traveling along the section under consideration.

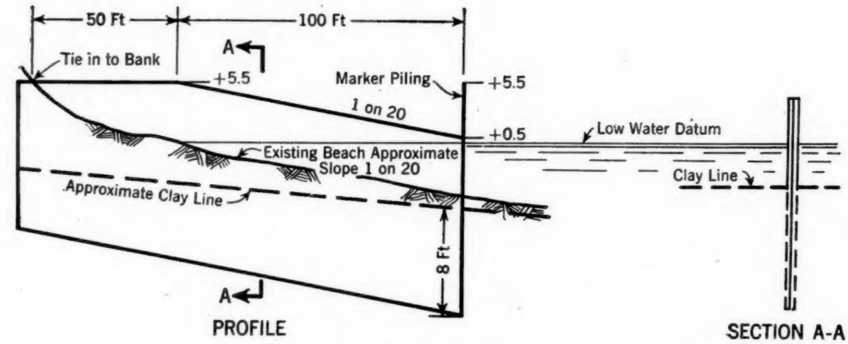


FIG. 2.—SHEET STEEL PILING GROIN FOR NORTHERN LAKE PLAIN SECTION

2. *Lake Border Moraine Section.*—This section of shore is developed for the most part as a residential area of fine homes. The shore line has been generally stabilized by the construction of protective works, although some sections in the northern part are subject to erosion. The rate of drift varies from lean in the north to moderate in the south. Enlargement of the beaches in the northern part of the section would be dependent upon artificial fill.

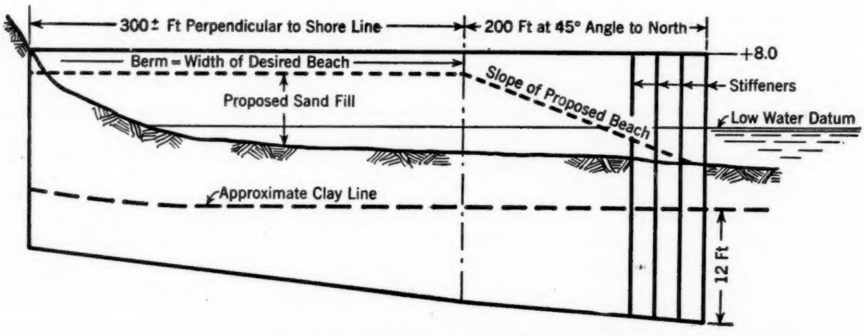


FIG. 3.—STEEL JETTY, SOUTHERN LAKE PLAIN SECTION

The type of shore improvement for this section is the same as that proposed for the northern lake plain section, except that the sloping section of the groin is 1 on 30, which conforms to the natural beach slope in this region. Such a slope increases the over-all length of the groin to 200 ft. The number of groins constructed per year should be determined by the method indicated for the northern plain section.

3. *Southern Plain Section.*—This section of shore line is highly developed for parks and residences. The northern zone is subject to erosion, but this erosion has been controlled by protective structures such as riprap and bulkheads. The rate of drift varies, being heavier in the southern zone. A typical section of the proposed improvement for providing additional beach area and protection is indicated in Fig. 3. The length of the jetty would depend upon the area of beach desired. Sand fill may be pumped in if the requirements for the beach will not be satisfied by natural accretion processes. Protection and enlargement of the beach areas could also be provided by the construction of a system of groins and artificial fill, but since the length of public property along the shore line is limited, the jetty type of construction is recommended to improve and provide the needed beach areas.

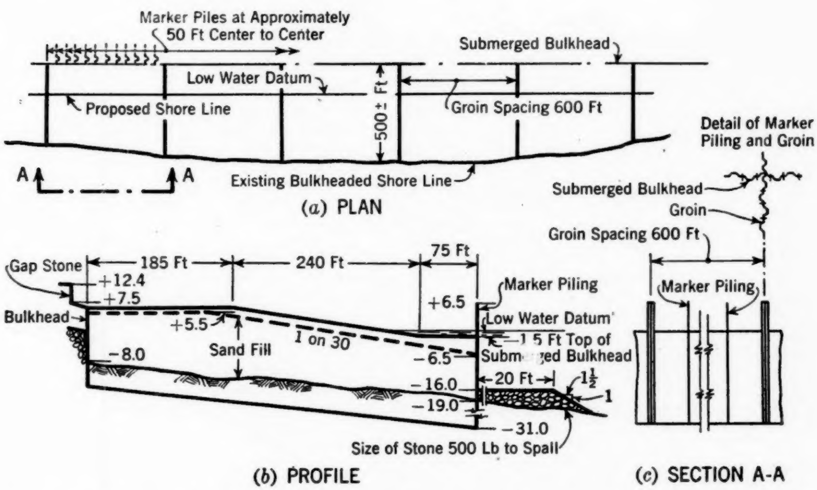


FIG. 4.—SUBMERGED OFFSHORE STEEL BULKHEAD AND STEEL GROINS FOR ARTIFICIAL FILL SECTION

4. *Artificial Fill Section.*—The bulkheads in this section have stabilized the shore line, and the development of beaches has depended upon artificial fill because of the lack of littoral drift. The urgent problem is the construction of adequate beaches for the dense urban population. Based upon a peak load attendance of about 8% of the population, and allowing 75 sq ft per person (generally accepted as the area desired for recreation) the beach area required for Chicago would be 22,800,000 sq ft. Existing beaches in the Chicago area total 9,216,000 sq ft, leaving a deficit in beach area of 13,584,000 sq ft. The only portion of the shore line available for development of additional recretional beaches in Chicago lies lakeward of the existing sea wall. This necessitates construction of beaches in relatively deep water. The Park District of Chicago believes that, ultimately, the entire Chicago lake front may be required for beach purposes to meet the demand for recreation. The typical proposed improvements for this section would consist of a sand fill retained by a steel sheet piling submerged breakwater, a steel sheet piling pier, and steel sheet

piling impermeable intermediate groins to retard the migration of the sand. The proposed construction is indicated in Fig. 4.

## Summary

From the description of protective works, it is apparent that the problems of arresting shore line erosion involve many geological and engineering considerations. The proposed solutions discussed call for the gradual building of new beaches to provide protection for the shore line, as well as recreation for the neighboring population. If beaches are not desired, or if they are considered too expensive to provide protection against wave action, then the next best method to prevent erosion of the shore appears to be the use of some means of direct armoring, such as by bulkheads or riprap revetment.

# CURRENT PAPERS AND DISCUSSIONS

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